Best Practice for Pipeline Wetland Crossings

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TERMS OF REFERENCE

This work has been conducted by Paterson & Cooke for the Federation for a Sustainable Environment. The purpose of this document is to illustrate the best practice to be performed by an engineer or designer when designing an overland pipeline that crosses environmentally sensitive areas.

CONTENTS

1. INTRODUCTION

Paterson & Cooke (P&C) has offered to assist the Federation for a Sustainable Environment (FSD) with the preparation of a best practice document of overland pipelines in environmentally sensitive areas.

This document summarizes the mitigating measures proposed to reduce likelihood of pipeline failure as well as reducing the environmental impact in the event of pipeline failure.

The construction methodology is discussed which will give the reader insight in the procedures involved with the construction of the pipeline and supports located within a wetland.

2. RIVER AND WETLAND CROSSING PIPELINE INTEGRITY

Before any pumping system can be installed, a design process has to be followed to ensure the pipeline and pumping system can deliver the duty flow rate and tonnage throughput, the materials and equipment selected are adequate for the medium being pumped and that it complies with the various regulations and design codes (where applicable).

2.1 Pipeline Design Codes

The engineering design of any pipeline and pumping system can be categorized by the pipeline size, operating pressure and contents. The larger the pipeline and the higher the pressure, the more onerous the design guidelines become. In South Africa we have a code that categorizes such pumping systems, namely SANS 347, “Categorization and conformity assessment criteria for all pressure equipment”.

This document starts off by categorizing the fluid being pumped as “dangerous liquids” and “non-dangerous liquids”. Dangerous liquids, or “Fluid Group 1”, are classified to have explosive, flammable, corrosive, toxic and/or oxidizing properties. Non-dangerous liquids, or “Fluid Group 2”, comprise fluids other than those in Fluid Group 1. The design of a non-dangerous fluid system which includes most slurries in the mining industry of South Africa, typically requires a design with “sound engineering practice”. This term refers to proper hydraulic design such as pipeline friction calculations, pressure rating selection, material selection etc. However, the majority of these systems do not require signoff by a professional engineer registered with the Engineering Council of South Africa (ECSA).

A system that transports a Fluid Group 1 will have more onerous requirements. If a Fluid Group 1 system operates above 1000 kPa and the pipe is larger than 200 mm in diameter, the system is categorized as a Category II which requires it to be designed and signed off by a professional engineer.

Long distance, high pressure slurry and oil transport pipelines are normally designed in accordance with the onerous ASME B31.4 code. Although this code is not applicable to “standard” mining tailings slurry pipelines, it contains several useful design guidelines that can be used by a pipeline design engineer. The code states the following relevant guidelines for best practice:

- Chapter II of the code provides the engineer with guidelines to which a pipeline should be design to. The engineer has to take cognisance of the various design loads that will be experienced by the pipeline such as sustained loads (pressure and weight), occasional loads (temperature changes, water hammer) and construction loads. The design factors associated with each of the loads are discussed and listed in great detail in the code.

- Section 403.2.2 provides guidance with regards to pipeline wall thickness allowance such as allowance for corrosion if no protective internal coating or lining is used. Therefore, if an engineer wishes to use unlined bare steel piping he/she has to allow for additional wall thickness for corrosion that will take place during the life of the pipeline.

- Section 462.2 outlines the requirements for internal protection of pipelines from corrosion: “When designing a new or replacement pipeline system, or additions or modifications to existing systems, measures should be considered to prevent or inhibit internal corrosion, or both. To preserve the integrity and efficiency of a pipeline in which it is known or anticipated that a corrosive liquid will be transported…”

Once the design has been completed and the pipeline is procured and constructed, ASME B31.4 provides guidelines for the inspection, testing and maintenance of the pipeline:

- Section 437.1.4 (1) states that a pipeline should be visually inspected for defaults after construction: “All slurry transportation piping systems within the scope of this Code, regardless of stress, shall be tested after construction.”.

- Section 437.4.1 requires that most pipelines be pressure tested with water during commissioning: “Portions of piping systems to be operated at a hoop stress of more than 20% of the specified minimum yield strength of the pipe shall be subjected to not less than 1.25 times the internal design pressure at that point for not less than 4 hr.”

- Section 454 outlines the requirements for the event of a pipeline failure: “A written emergency plan shall be established for implementation in the event of system failures, accidents, or other emergencies, and shall include procedures for prompt and expedient remedial action providing for the safety of the public and operating company personnel, minimizing property damage, **protecting the environment**, and limiting accidental discharge from the piping system.”

- Section 463.1 outlines the requirements for the external protection of pipelines exposed to the atmosphere: “Steel pipelines exposed to the atmosphere shall be protected from external corrosion by a suitable coating or jacket, unless it can be demonstrated by test or experience that the materials are resistant to corrosion in the environment in which they are installed.”

In summary, there are regulatory and design codes than can be used as guidelines for best practice when designing and installing slurry pipelines.

2.2 Pipeline Design

The engineering design phase is essential for the integrity of any pump and pipeline system. The engineer needs to calculate the optimal pipe size, pressure rating and select the most appropriate pipeline material and internal lining. Equally as important is to take cognisance of the terrain and environment that the pipeline will traverse.

For some pipelines, depending on the length and size, a transient analysis is required. The analysis needs to consider numerous abnormal cases that the pipeline might experience in its lifetime. Amongst these cases are rapid valve closures, pump trips, start-up and formation of air voids within the pipeline. In all cases the pipeline pressure rating need to be sufficiently specified to accommodate the occasional pressure wave resulting from the transient events.

In summary, careful engineering design is required to provide a mechanically and structurally sound system.

3. RIVER AND WETLAND CROSSING CLASIFICATION

P&C have previously used the following classifications of river and wetland crossings in order to specify appropriate mitigating factors that will be suitable for the type of crossing:

1) Passing within 100m of wetland perimeter.

2) Narrow river crossing.

3) Wide wetland with river in centre.

These three types of river / wetland crossings are discussed in more detail in this section.

3.1 Class 1: Passing Within 100m of a Wetland

For this type of wetland crossing the pipelines do not cross a visible river or stream but runs within 100m of a wetland perimeter.

It is proposed that the pipelines be supported on reclaimed railway sleepers placed at predetermined intervals. The pipeline should not contain any flanges for the full length of the wetland / river crossing and it should ideally contain a continuous HDPE internal liner for internal wear / corrosion protection.

3.2 Class 2: Narrow River Crossing

The pipelines will be supported on reclaimed railway sleepers placed at predetermined intervals as it approaches the wetland. 50m before and after the river crossing the pipelines will be supported on in-situ cast concrete supports with foundations located at predetermined intervals. These plinths can be fitted with steel straps to keep the piping seated during transient conditions. Concrete supports should be constructed on both sides of the river / stream with an unsupported pipe span across the river of a length deemed structurally sound. The pipeline, which contains an HDPE internal liner, should not contain any flanges for this 100m length of pipe with the flanges of the continuously welded spool located within the designated spillage paddocks.

As an additional precautionary measure, the pipeline can be fitted with inspection points which consist of a welded port with plug on the pipe wall (weldolet) which only penetrates the steel wall and not the HDPE internal liner. If the internal liner is damaged it can be picked up during a routine inspection as the inspection point will let through liquid when opened. Steps can then be taken to replace the section of pipe at the wetland prior to further failure of the steel pipe. All flanges within 100m of the wetland should be fitted with spray prevention plates as indicated in Figure 1 which will reduce the risk of flange gasket leakage spraying into the wetland.

Figure 1: Flange Spray Plate

The details of this type of river crossing are illustrated in Figure 2 and Figure 3.

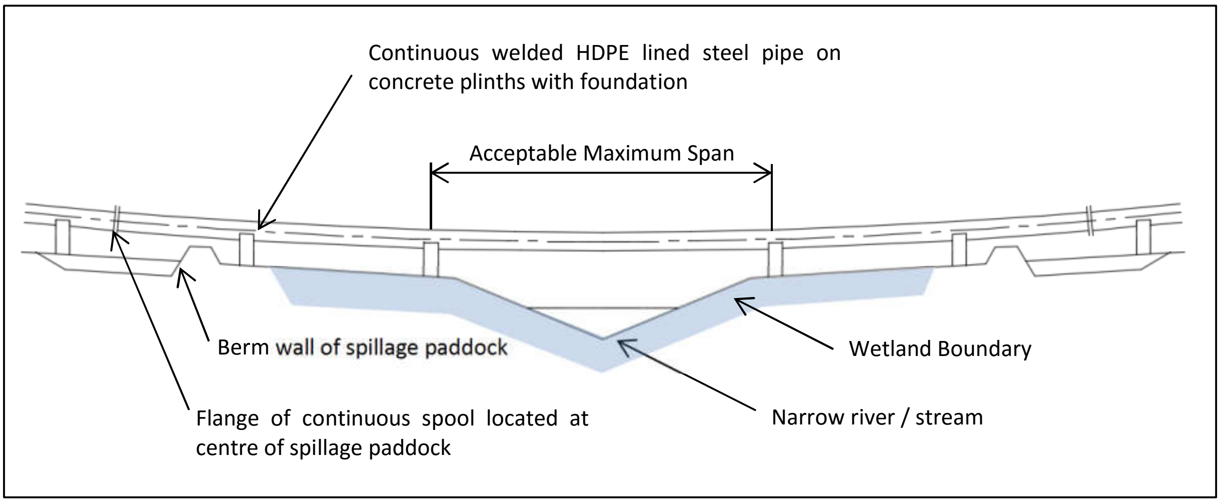

Figure 2: Class 2 River Crossing Cross Section

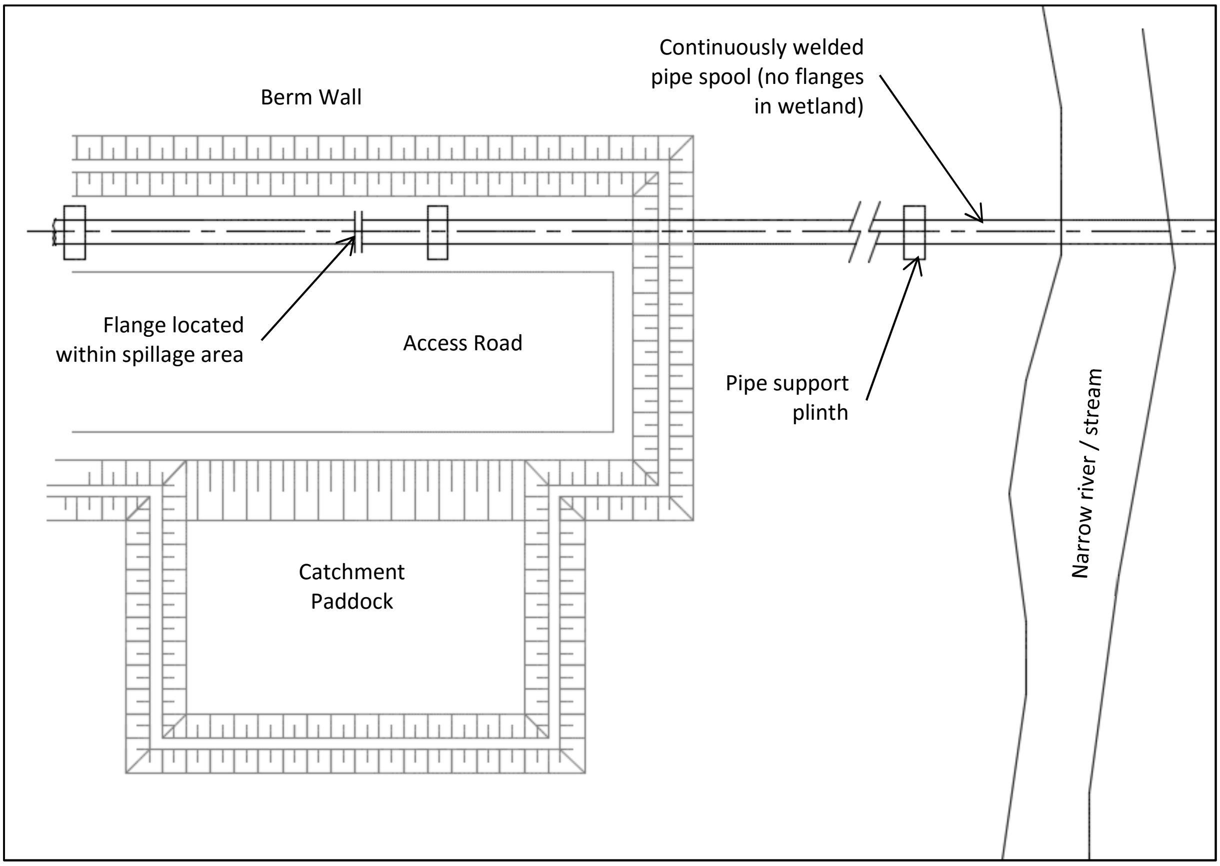

Figure 3: Class 2 River Crossing Spillage Paddock Plan View

3.3 Class 3: Wide Wetland with River

The detail of this type of river crossing is similar to that depicted in Figure 3 with the exception that the distance between the spillage paddock and river is further apart.

3.4 Spillage Management

It is recommended that a pipeline is fitted with a leak detection system such as a flow meter at the pump station discharge and at the delivery point which is linked to the SCADA system. If a leak occurs the leakage detection system will trigger an alarm which will prompt the operator to initiate an emergency shutdown of the pumps. The isolation valves at the pump station will close to prevent draining of the line.

The spillage paddock should be designed to contain the volume of slurry / water that will naturally drain from the high points to the valley where the paddock is located. In the event of multiple pipelines crossing a river at the same point, the largest bore pipeline that runs through a crossing can be used for the calculations as it can be assumed that only one pipeline will fail at a given time.

The spillage paddocks should be maintained regularly in order to have the paddock storage capacity available at all times. During storm events the paddocks will have to be drained of clean water. Also, sludge will have to be removed as soon as possible after a pipeline leakage or failure.

In some cases, where a pipe bridge has to be constructed due to topographical or practical reasons, one can include a pipe tray that will house the pipelines for the full length of the wetland or river crossing (Figure 3). This is elaborate, but if the fluid that is transported is categorized as toxic, this could be considered as a safe alternative.

Figure 4: River Crossing with Pipe Tray

Usually the terrain leading up to a river crossing slopes towards the river or wetland and it is considered good practice to provide a berm wall on either side of the pipe corridor that will store or channel spillage to the paddocks located closer to the crossing. An example of this arrangement is illustrated in Figure 5.

Figure 5: Spillage Trench

4. CONSTRUCTION METHODOLOGY

The following information can be used as a guideline for good practice when constructing a water or slurry pipeline.

The pipeline plinths that will be used to support the pipeline in the wetland needs to be carefully constructed to prevent unnecessary damage to the wetland. The positions need be set out, the excavation planned carefully and the use of heavy machinery should be limited. Once the plinths are casted, the proper backfill material should be used to fill open voids around the foundations.

Once the plinths are all in place, the pipe spools can be delivered to site and stored outside of the wetland boundary. The pipe spools should be welded together outside of the wetland and can be pulled over the wetland by using the casted plinths as a supporting surface. It is recommended that a mobile crane is used to manoeuvre the pipeline across the wetland without entering the wetland itself.

5. CONCLUSION

Any pump and pipeline system requires some form of design. Depending the size and length of the pipeline, the operating pressure and the process fluid, each system will require a different level of design. The design and regulatory codes associated with water and slurry pipelines were discussed and how it can be used as guidelines for the design of such systems.

The high level hydraulic design process was discussed to illustrate the importance of properly designing and understanding a system, especially if it crosses wetlands or environmentally sensitive areas.

The various wetland and river crossings were categorized based on P&C's experience to which different sets of mitigating factors were applied.

The construction of pipelines, including the supporting plinths, were discussed in the document. These guidelines can be used in conjunction with the environmental consultants and authorities to construct a pipeline within a wetland using the most suitable and environmentally friendly methods.

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